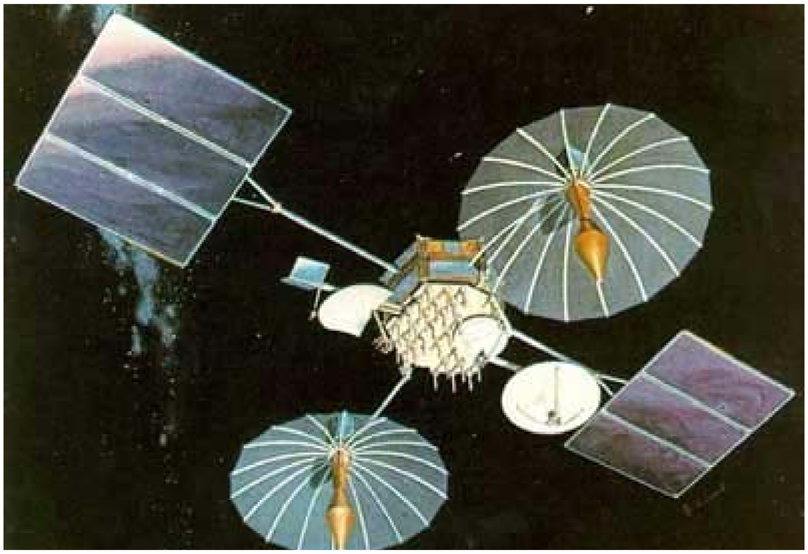
National Aeronautics and Space Administration

NASA Case Study GSFC-1009C-1

TDRSS: Fixed-Cost versus Cost-Plus Contracting

In the early days of the U.S. space program, the system of controlling and collecting data from low Earth-orbiting satellites included a series of ground stations scattered around the world. This worked well because the satellite population and data rates were low and signal strength was high. However, passes were short, because of the low altitude of the spacecraft. Also, more spacecraft were coming online. More contact with the spacecraft required more ground stations. This was both a workforce problem and a political problem. Some countries were not interested in cooperating with the United States in hosting ground stations, and several critical NASA ground stations closed just before major space missions owing to political instability in host countries.



First-generation tracking and data relay satellite, artist's concept. NASA image

By the late 1960s, low Earth-orbiting satellites were in view of the existing ground stations only about 15% of the time. The proposed manned missions would require more continuous coverage, even if the existing ground network was augmented with the expensive space-tracking aircraft and ships used in the *Apollo* network. The proposed solution was to substantially increase coverage with a series of specialized geosynchronous communications satellites tracking the low Earth-orbiting satellites and relaying the data to a single U.S. ground station. This concept, called the Tracking and Data Relay Satellite System (TDRSS), would provide continuous coverage and keep all ground-system assets on U.S. soil.

As early as 1967, within 10 years of the start of the U.S. space program, phase A and B definition studies for a possible geosynchronous satellite system were launched at the Goddard Space Flight Center (GSFC). Such a system would include at least two Tracking and Data Relay Satellites (TDRSs) in geosynchronous orbits that could track low Earth-orbiting satellites over most of their orbits and relay their data to a U.S.-based ground station that was constantly in view. From there, the data would be relayed to the appropriate science centers. The advantages would be significant: very long passes, high data rates over extended parts of the orbit, and more satellites accommodated. Perhaps most importantly, the number of ground stations in other countries could be reduced.

These studies continued into the early 1970s and included the successful demonstration in 1974 of the capability of the space-based tracking system. Thus, it was decided to go ahead with TDRSS. There was, however, a potential problem with funding the system.

Financing

In the mid-1970s, NASA was under severe budgetary pressure because of high inflation and the end of the *Apollo* program. The agency had to trim the budget to fund the shuttle program. TDRSS would be very expensive, involving a number of spacecraft and a sophisticated ground system, and NASA's administrator did not want to ask Congress for appropriations that might interfere with shuttle development.

A solution was proposed that instead of building its own new system, NASA could lease communication services from a commercial provider. The contractor would be asked to build the system with private financing and lease back services to NASA for at least 10 years. NASA would pay for those services over that period using appropriated funds. The system would also have commercial communications capabilities. The revenue from the NASA lease and the commercial income would pay for the system and provide the profit for the company. The expectation was that NASA could save money with such an arrangement.

When the private-financing plan fell through, it was decided that industry participants would borrow money directly from the Federal Finance Bank (FFB), part of the U.S. Treasury. The required special permission was obtained from the U.S. Congress, and NASA guaranteed the loan. The money would be "off-budget" for NASA initially and paid back with appropriated funds during the 10-year operation period. An interesting part of the arrangement was that it allowed the contractor to borrow money from the FFB without NASA's approval though the contractor was required to notify NASA in writing when it withdrew funds.

The TDRSS Program was established by NASA in 1973 and assigned to GSFC. Acquisition for the first series began in 1974 with the request for proposals (RFP), and in 1976 a 10-year, fixed-price (FP), leased-services contract worth $786 million was signed. The prime contract for the first series of six spacecraft and the ground system was won by Western Union's subsidiary Western Union Space

Communications (WUSC). TRW, Inc., was subcontracted for the space segment and Harris Corporation for the ground segment, both signing FP contracts for their respective deliverables.

As the government was buying what it thought was a known service over time, it chose to enter into an FP contract with WUSC for leased services in order to avoid large, up-front capital outlays that would compete with shuttle development. According to the government's Federal Acquisition Regulation (FAR) Web site, an FP contract "provides for a price that is not subject to any adjustment on the basis of the contractor's cost experience in performing the contract. This type of contract places upon the contractor the maximum risk and full responsibility for all costs and resulting profit or loss." The more typical (for NASA) cost-plus award fee (CPAF) contract is defined by FAR as,

> A cost-reimbursement contract that provides for a fee consisting of (a) a base amount (which may be zero) fixed at inception of the contract; and (b) an award amount, based upon a judgmental evaluation by the Government, sufficient to provide motivation for excellence in contract performance.

Since NASA was not directly involved in TDRSS development and would not own the assets, the FP arrangement seemed appropriate.

The First Series

The TDRSS project office at GSFC had responsibility for both the space and ground segments, with a deputy project manager assigned to each. The NASA challenge was to develop three major systems simultaneously—the user, ground, and space segments. NASA retained total responsibility for developing the user segment and portions of the ground segment, and contracted with WUSC to develop the remainder of the system, including the space segment and the part of the ground segment that controlled the TDRSS constellation and served as a terminus for all TDRSS communications channels.

GSFC gave out contracts for user-transponder design and development to several companies, and designed and constructed an operations facility and computer complexes for TDRSS schedule planning and user orbit determination at GSFC. The contract for the remainder of the TDRSS space and ground assets was awarded to WUSC, based on low bid. TRW was to perform end-to-end system architecture, system design and engineering, ground- and space-segment architecture, and to design and build the space segment. Harris Corporation was to build portions of the ground system including the antennas and ground-communications equipment. The original launch readiness date for the first spacecraft was set for 1978. WUSC would borrow money from the FFB twice per month to fund development, which was to be repaid, including interest, by NASA.

The proposal stipulated dual-use spacecraft, meeting all government TDRSS needs and carrying a C- and Ku-Band communications-payload capability for commercial use.[1] One difficulty NASA had with the RFP was being able to specify the system functionality it needed to satisfy its service requirements 13 years into the future.

[1] The entire system was designated the Shared Services Tracking and Data Relay Satellite System (SSTDRSS). It consisted of the TDRSS program and the Western Union Advanced Westar Commercial Communication Program.

The WUSC plan was for two of the six satellites to be dedicated to TDRSS, one as an on-orbit spare available for rapid TDRSS or WUSC Advanced Westar (AW) replacement, and two of the remaining three to be dedicated to AW. The sixth was to be an on-the-ground spare to be used in the event of a launch failure and a replacement for the in-orbit spare if necessary.

Early Changes during Development

Early on there were problems and changes that had major effects on cost and schedule. These changes were government-driven and, under the FP arrangement, were not absorbed by the contractor. The first was a potentially severe radio-frequency interference problem caused by high-powered, ground-based radar transmissions over Eastern Europe. NASA was unaware of this problem when the RFP was written, so the system specifications did not take those into account. This could have changed the entire design, but the issue was resolved with no significant design changes.

TDRS-A deployed by Challenger STS-6, April 1983. NASA image

The real problem was the contract. With a CPAF contract, a GSFC team easily could have met with the TRW team and determined a solution together. A change order could have been issued quickly and the delay minimized. However, GSFC had bought off on the initial design and, under FP terms, the GSFC project team was not prepared to interact directly with TRW at first—it was to be "hands off." WUSC had no particular expertise in this matter; TRW did, but was not part of the GSFC–WUSC contract interface, so TRW waited for direction. WUSC wanted NASA–TRW interfaces to go through WUSC. One estimate put the cost of the delays at $70 million.

Other changes affecting cost and schedule included the decision to move TDRS-A from an expendable launch vehicle (ELV) to the shuttle for launch.[2] This was costly for two reasons. First, TDRS-A had to be changed to conform to shuttle safety standards, which consumed a lot of time working with Johnson Space Center (JSC) and Kennedy Space Center (KSC). Second, an Air Force inertial upper stage (IUS) had to be added to enable the spacecraft to get to synchronous orbit after being deployed by the shuttle in a low-Earth orbit. Headquarters held JSC responsible for the IUS-to-shuttle interface, which worked well, but the shuttle was still being developed, which complicated the process. For example, JSC did not have the shuttle load information. Those changes added approximately $80 million.

[2] A potential weight problem was solved by going to the shuttle. When the propulsion system was sized in 1976, they forgot to include a weight budget for station-keeping fuel for the commercial function. (NASA did not require station keeping.) This could have added more than 1,000 pounds, which would have required a larger ELV—a Titan. That would have had to been absorbed by the contractor per this FP contract.

In 1980, while TDRS-A was in integration and the ground system was far along, the Air Force decided that it was necessary to upgrade the communications security between the ground station and the flight segment, so encryption was added to the link.[3] This required major changes to the hardware and software in the ground segment and to the hardware in the flight segment, costing an estimated $50 million to $100 million. More money was borrowed from the FFB.

The TDRS-A launch, originally scheduled for 1978, was eventually delayed to 1980 because of the earlier changes. The shuttle development and Air Force delays slipped launch to April 1983.

Space-Segment Development

Technical development went relatively well, but there were some difficulties. WUSC was the prime contractor but had little experience developing space systems. As a result, communications among contracting parties was often difficult, especially between GSFC and WUSC. Eventually the GSFC team was able to work with TRW despite WUSC, which was mostly concerned with maintaining the viability of the commercial C- and Ku-Band links and resisted any changes that might affect them. This was to be expected under an FP contract. WUSC had neither the financial strength nor the inclination to assume liability for correcting space- or ground-segment flaws. Consequently, there was a temptation to accept the service penalties that resulted from operational outages rather than making the fixes required. NASA found that unacceptable.

White Sands Ground Terminal. NASA image

Ground-Segment Development

The TDRSS ground segment consisted of multiple parts, some developed by GSFC through the WUSC contract and some developed within GSFC. The data from the user satellites (NASA and other government users) and from the commercial links would flow through the TDRSs to the ground station in White Sands, New Mexico. White Sands Ground Terminal (WSGT) was developed by WUSC. In the same building was the NASA Ground Terminal (NGT). All government data flowed from the WSGT to the NGT where it was quality-checked and sent to mission control centers and data-processing facilities. Some mission and status data were sent to the Network Control Center (NCC) at GSFC. The NCC, in

[3] In 1981, TDRSS was declared a national asset, meaning that it would fulfill critical national needs. This was driven by the Air Force and the shuttle's dependence on TDRSS to provide nearly continuous contact with the ground.

turn, returned schedule and state vector data back through the NGT to the WSGT for control of the space segment. The commercial data, captured by a separate C-Band antenna, flowed from the WSGT straight to other commercial facilities.

Contractually, the ground and space segments were similar. The difficult interface on the space segment with WUSC between GSFC and TRW was duplicated in the ground segment. WUSC was between GSFC and Harris and between Harris and TRW. A more-logical arrangement would have Harris as a subcontractor to TRW. Despite the clumsy arrangement, GSFC, TRW, and Harris fixed the problems, but the initial lack of functional requirements in the TDRSS service specification did have an impact. As the real requirements were brought to light, most flowed directly into the ground-segment specification. A relatively simple 100-page ground-segment specification grew to more than 300 pages.

Developing the WSGT software proved to be far more difficult than building the hardware. Changes and problems were numerous, including quality problems, adding encryption, and other requirements' changes. The WSGT was built by WUSC to commercial standards—not up to NASA standards. Multiple-access (MA) service did not work well at first and developed a bad reputation in the user community, which put larger-than-expected demands on the single-access service. Unstable MA ground receivers were the primary issue.

First-Series Launch Record

- **TDRS-A** launched April 5, 1983
- **TDRS-B** destroyed January 28, 1986, in the *Challenger* disaster
- **TDRS-C** launched September 29, 1988
- **TDRS-D** launched March 13, 1989
- **TDRS-E** launched August 2, 1991
- **TDRS-F** launched January 13, 1993
- **TDRS-G** launched July 13, 1995 (replacement for TDRS-B)

Contractor Changes

Modification (mod) 37 to the contract, effective June 27, 1980, was a novation[4] of the contract to the Space Communication Company, known as Spacecom. Western Union sold 25% of the shares to Fairchild and 25% to Contel Federal Systems, retaining 50%. This event is known as "reformation." Between 1984 and 1986, Contel bought all of Spacecom, and by mod 555 on February 15, 1989, the contractor was Contel Federal Systems. The GSFC project had been frustrated with Western Union, because of its lack of expertise in the space field, and in fact Western Union had been seen as an

[4] Novation is the substitution of one-performance obligation with a new obligation, or replacing a party to an agreement with a new party.

impediment between TRW/Harris and GSFC. Now there was a sense that the new partners brought at least some technical expertise to the table, so the situation improved somewhat.

During 1989 to 1990, a "mini-reformation" took place. At that time, there were three spacecraft in orbit. Previously, NASA owned nothing and had bought services from WUSC/Spacecom. Contel now had TRW and Harris as subcontractors. The service contract had small penalties for interruptions of service, but the FFB loan had to be repaid whether the users were served or not. On the other hand, the daily TDRSS operating costs had to be paid out of the revenue stream from the Advance Westar (AW) C- and Ku-Band services. Consequently, Contel had a heavy incentive to convert TDRSS assets to AW assets in the event of an AW failure, but almost no incentive to convert an AW asset to TDRSS in the event of a TDRS failure. It became obvious to the government that something had to be done about the contractual arrangement.

You Decide

- Sketch a diagram of the organizational structure of the TDRSS program, showing the relationships between the key organizations. What implications does this kind of structure have for project management and performance? Do you see any parallels with your projects?
- What would you recommend regarding the current TDRSS contractual arrangement? Should you stay the course? Renegotiate the terms? How about buying out the contractor?
- What might be some of the unanticipated consequences of contracting relationships?
- How can the lessons learned from TDRSS apply to future NASA projects?